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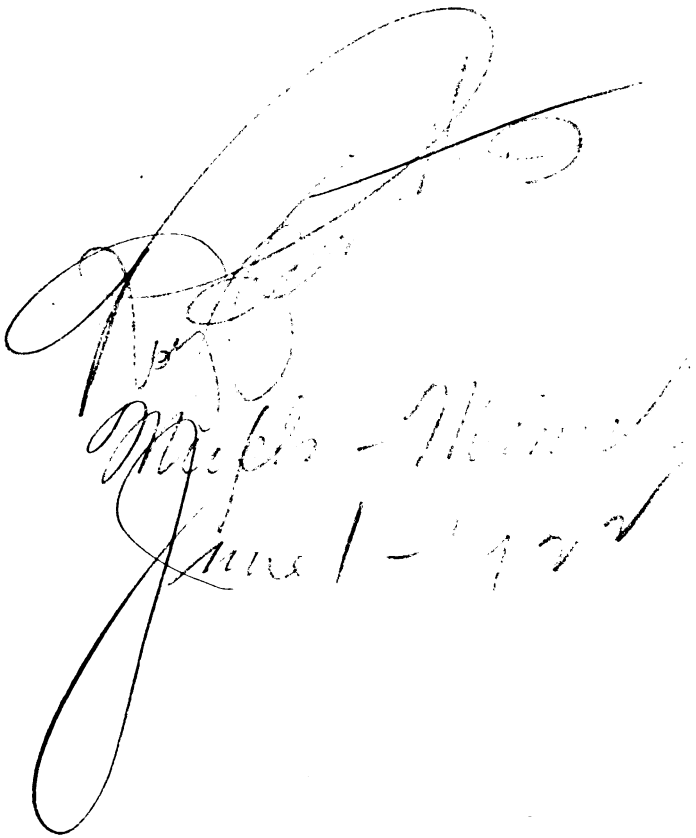
JOHN F. DOWNEY



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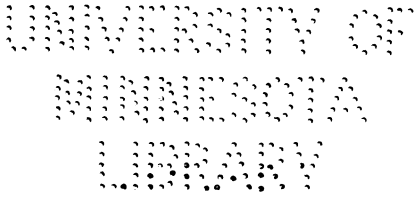

WHILE these pages deal with many of the most recent achievements of the professional astronomers with the telescope, the spectroscope, and the camera, few technical terms are employed, and the presentation will be readily understood by the general reader. The object is not so much to acquaint him with the isolated facts, wonderful though they are, as to place these facts in their proper relations to one another and to obtain from them enlarged conceptions of the Creator and Controller of a universe so vast and complex.

THE NEW REVELATION THROUGH THE SPECTROSCOPE AND THE TELESCOPE

I

REVELATION THROUGH THE SPECTROSCOPE

I THINK it is a safe proposition that all of God's revelations to mankind have been through human agencies. Jehovah is not reported as ever having spoken in thunder tones from the clouds or written in blazing letters on the sky His commands to mortals. True, the people heard the thunderings, felt the quaking, and saw the smoke and lightning of Sinai; yet the message was delivered not to them directly, but through Moses. When in olden time He had a message for men, He chose some prophet or seer through whom to give it—a Moses, a Samuel, an Isaiah, or a Jeremiah. Even when He wished to make to men that most important of all revelations, His plan of redemption, He chose that it should be through the son of

Mary, born, nourished, and reared as are other men, human in all things except the Spirit dwelling within Him. And when His work was ended, the message had been delivered to but a few followers, and it was left for them to spread it abroad. God does not now speak directly to heathen nations; He simply puts it into the hearts of those who know Him to carry to these the glad tidings. He says to His disciples, "Go, preach the gospel to every living creature." I think we should, therefore, expect no additional revelations except through human agency.

I also think it a safe proposition that when God makes a revelation to men, it is always suited to their conditions. When He wished to reveal Himself to a primitive people, rendered more ignorant and gross by generations of servitude under the hardest of task-masters, He gave them a worship suited to their understanding. Incapable of appreciating or exercising a purely spiritual worship, He gave them a material one, consisting of forms, ceremonies, offerings of

sacrifices. Unable in their simplicity to come near to God in soul cummunings, He gave them a worship consisting of something tangible. As the idea of a future life was too vague to serve as an incentive to virtuous living, the rewards and punishments mentioned appertained to this life. In the Old Dispensation it was length of days, riches, a numerous posterity, and tribal prosperity that were promised to the righteous.

When people, through the cumulative discipline and development of many generations, had reached a mental and spiritual state to render it possible, a new revelation was made: the event foreshadowed through the ages at last arrived, and Jesus the Christ, Heaven-sent, appeared as the founder of a spiritual religion, whose worship was in the heart and whose reward or punishment was mainly in a future life. There is an acknowledgment in the Scripture not only that the first revelation was incomplete, but that it was imperfect. Paul says to the Hebrews (8: 6-10): "He is the Mediator of a better

covenant, which was established upon better promises. For if that first covenant had been faultless, then should no place have been sought for the second. For finding fault with them, He saith, Behold the days come, saith the Lord, when I will make a new covenant with the house of Israel and with the house of Judah: Not according to the covenant that I made with their fathers in the day when I took them by the hand to lead them out of the land of Egypt. . . . For this is the covenant that I will make with the house of Israel after those days, saith the Lord; I will put My laws into their mind, and write them in their hearts: and I will be to them a God and they shall be to Me a people."

We are not to suppose that the revelation was complete even with the redemption that came with the Savior. Christ tells His disciples that He was keeping much back because they were not yet prepared to make use of it. He said (John 16: 12, 13): "I have yet many things to say unto you, but ye can

not bear them now. Howbeit when He, the Spirit of truth, is come, He will guide you into all truth; . . . and He will show you things to come." Thus additional revelations were promised, and through the enlarged perceptions of men these additional revelations have come; and Christ's religion means far more to-day than it ever meant before. We understand as the Jews, with their traditions and materialistic ideas, never could understand Christ's statement, "Behold, the Kingdom of God is within you."

If Christ had left on record sayings which His disciples could not understand, they would not have been revelations to them; but to any coming after, no matter how many centuries, who should be wise enough to understand them they would be revelations. In this way every discovery in the material universe which shows us some attribute or method of God which we did not know before is a revelation from God of Himself. No matter that it has existed through the ages without being read, it is a

revelation to those who can now read it. What revelations of Himself as a wonder-worker has the microscope made! what revelations of His power, wisdom, and majesty has the telescope made! what revelations of the subtile forces at His command have we had through the recent developments and applications of electricity! As in these latter years men have been enabled to look down into Nature's hitherto invisible myriad life and up to worlds and blazing suns above us and to those other suns so far beyond the reach of the eye's unaided ken, how their conceptions of the Creator have expanded! and the farther we peer into His work, the more wonderful does He become.

What a wonderful element is light! with what glory it floods the heavens! with what beauty it bathes the earth! with what marvelous tints does it touch the flowers which it evokes from the dead soil! with what a mellow glow does it illuminate our crescent moon, the far-off satellites of Jupiter, and the superb rings of Saturn! with what swiftness

does it flash through space—one hundred and eighty-six thousand miles a second—a swiftness that would carry it eight times around this earth between two consecutive ticks of the clock! Does this agent, that has forever flooded the universe and revealed it to the eyes of men, bring any new revelations? Does that light which has charged across those dizzy depths bear a readable message from yon twinkling star? Truly, yes. For ages upon ages it has been flashing its message, but men could not read it—they did not know the language in which it was written. But a few years ago God permitted a man to learn the language, and as he has taught it to the world, we now, with ease and confidence, read the revelation.

When in 1675 Sir Isaac Newton received into a darkened room a beam of light through an orifice and then passed it through a triangular prism of glass, what a marvelous transformation did he witness! There on the screen, from that colorless sunlight, he had the gorgeous colors of the bended bow of the

heavens. Thus he learned that light is composed of seven colors, and that the rays of different colors in passing through a prism are unequally bent, thus separating them. In 1802 Wolaston received the light through a narrow slit parallel to the edge of the prism, instead of through an orifice, and, the colors no longer overlapping, obtained a spectrum of unprecedented purity and beauty. One day, on looking through the prism at the slit, thus receiving the spectrum directly into his eye, he discovered seven dark lines parallel to the slit. He had no suspicion of what those dark lines were destined to reveal.

In 1814 the celebrated German optician, Fraunhofer, independently discovered these lines. While he was unable to interpret them, he instinctively felt that they would prove of importance, and proceeded to determine their exact position. To see them more distinctly, he viewed them through a telescope, and then saw many more lines. To separate them farther for more accurate measurement,

he passed the rays through two, and eventually through four prisms, and then, to his astonishment, he was able to count five hundred and seventy-six lines. In 1815 he accurately mapped three hundred and twenty-four of them. These are still called the Fraunhofer lines. He found these lines in all kinds of sunlight, whether direct from the sun or as reflected from the clouds, the moon, or the planet Venus, the positions of the lines being the same. He found that light from the stars contained these lines, but many of them arranged in a different order. He therefore came to this conclusion: that whatever produced these lines is inherent in the light and is not due to our atmosphere. This was only negative interpretation.

Here the matter rested, so far as the solar spectrum is concerned, for many years. In the meantime a great discovery in the same field was made. It was found that when a substance is burned and its light passed through the prisms, it gives a spectrum

crossed by lines—not dark lines, as in the solar spectrum—but bright lines. It was found that sodium, for example, gave two bright lines in the orange part of the spectrum, and always gave these lines; that potassium gave a line in the red and another in the violet, and always gave them. By an easy induction, physicists concluded that each elementary substance would give its own particular system of lines. This, then, would give a new method of analysis. This discovery created great enthusiasm, and physicists at once set about improving their instruments. The prisms, the telescope, and a tube containing slit and lens, called the collimator, were combined in one instrument, which was named the spectroscope. Sir David Brewster, Sir John Herschel, Tyndall, Huggins, Gladstone, Pluecker, Bunsen, Kirchhoff, and others proceeded to obtain the spectra of the different elementary substances, that they might use them as a key to the analysis of unknown substances. Through their skillful and painstaking labors

this has become a most powerful and satisfactory means of analysis. Some substances, like sodium, can be analyzed by burning them in a non-luminous gas flame; the harder metals, like iron, by turning them into vapor in an electric arc; and gases, like hydrogen, by confining them in a tube and making them luminous by the passage through them of an electric discharge.

While this new and infallible method of recognizing terrestrial substances by the bright spectral lines of their elements was thus developed, no interpretation of the dark lines of the solar spectrum had been found. In order to see whether the bright lines in the orange part of the sodium spectrum corresponded in position with any lines in the solar spectrum, Kirchhoff, a noted German physicist, in 1859 brought the spectrum of burning sodium by the side of the spectrum of the sun. He found the coincidence exact, which made it look as if there were sodium in the sun. But why should the lines be dark, while the lines of

terrestrial sodium are bright? In order to test still farther the coincidence, Kirchhoff threw the sodium spectrum on top of the solar spectrum by burning the sodium in front of the slit through which the sunlight was received. He expected that the dark lines of the solar spectrum would be made less dark by the bright lines of the sodium spectrum. To his great astonishment, they were not only not made less dark, but more dark. Furthermore, he found that when any artificial light giving a continuous spectrum was made to shine through a flame containing sodium vapor, the bright lines became dark, but retained their precise position. He at once saw that these lines were made dark by the absorption of the sunlight or other light by the sodium vapor. Another way of stating it is, that a vapor absorbs exactly the same kind of light, or the same rays, which the vapor itself emits. There flashed into his mind at once the explanation of the dark lines of the solar spectrum. It meant that the light from the more solid part of the

sun, called the photosphere, in passing through the light gases that lie above it, is absorbed in the same way that it was absorbed in passing through the vapor of sodium, thus giving dark lines where, were it not for the brighter light behind them, these gases would have given bright lines. These lines, then, although dark, are the characteristic spectral lines of the chemical elements in the sun; and since the lines of one element in a compound substance in no way interfere with the lines of other elements in the same substance, we have a means of determining the very materials of which the sun is composed. It is only necessary to compare the spectra of known elements with the solar spectrum; and when we find coincidence of lines, we can say with certainty that those elements are in the sun.

Since Kirchhoff's great discovery spectroscopes have been greatly improved. Not only have spectroscopes, containing batteries of prisms of high dispersive power, been attached to equatorial telescopes, but another

and better way of separating and dispersing the light has been employed. If fine parallel lines be scratched very close together on a piece of polished metal, this scratched surface will separate the light reflected from it as does a prism; and the finer the lines and the closer together, the greater the dispersive power. Professor Rowland, of Johns Hopkins University, supplied to the great observatories of the world wonderful gratings on which there were fifteen thousand lines to the inch. A photograph of the spectrum of the sun by this powerful instrument contains more than ten thousand lines. Beside it may be photographed the spectra of known substances and the comparison be made with great accuracy. In this way it has been found that thirty-nine of our common chemical elements enter into the composition of the sun. The presence of iron is made absolutely unmistakable by the coincidence of more than twenty-five hundred lines, and of calcium by the coincidence of seventy-five lines. Among the thirty-nine elements are

such familiar ones as carbon, oxygen, hydrogen, aluminum, potassium, nickel, copper, zinc, tin, lead, and silver. More than this: the stars are of the same general character as our sun; and though the nearest one is more than two hundred and seventy-five thousand times as far away as the sun, when the light of one of them is received into the spectroscope, the story of its composition is there written in unmistakable characters. A wonderful revelation, truly! Yonder by day blazes the sun; yonder by night, in the dizzy depths of space, twinkle the stars; yet we can, as it were, bring them into our laboratories, analyze their substance, and determine the very elements of which they are composed.

Newton proved that gravitation, which causes a body at the surface of the earth to fall, extends throughout the solar system, and acts by the same law. Observation on the binary stars shows that the law prevails throughout the universe. The same may be said of the three great laws known as

Kepler's laws. In other words, the mathematics and mechanics of the earth are the mathematics and mechanics of the heavens. It remained for the spectroscope to bring in our day the revelation that the chemistry of the earth is the chemistry of the heavens. While the sun yielded helium and the gaseous nebulæ yielded nebulum that were not found on the earth, helium has since been discovered among our elements, and nebulum probably will be.

The sun, when viewed through a colored or smoked glass, is seen to have a very regular outline, and so distinct that we would suspect the existence of no matter outside of it. During the total eclipse of 1842 astronomers for the first time beheld rose-colored flames extending far out from the concealed disk of the sun. Their observations were soon ended, as the phase of totality is of short duration. Not until after nine years would another total eclipse enable them to renew their observations. The immense flames, in various forms, were again

seen; but so brief was the time of their visibility that little could be learned about them. Not until after another nine years could they again be observed. During the brief interval of the total eclipse of 1860 these flames were not only seen and sketched by a large number of observers, but were actually photographed by De la Rue and Secchi. It thus became established that the visible body of the sun, called the photosphere, is completely surrounded by a layer of colored matter, which has been named the chromosphere, and that from this rise flames of immense size. At the eclipse of 1868 not only were telescope and camera used upon these appendages, but a far more powerful instrument of research, the spectroscope, and it showed that these immense flames are composed of glowing gases, and some of the characteristic bright lines were noted.

But while unsuspected and astonishing revelations were being made, the times of observation were separated by years and lasted but for minutes; so that during the

twenty-six years since these prominences were first seen only fifteen minutes had been afforded for their study. Their invisibility was due to the superior light of the photosphere of the sun and to the illumination of our own atmosphere. During an eclipse both of these obstacles disappear. But discovery was following fast upon discovery, and it only remained for Doctor Huggins to show that, by screening off the disk of the sun and widening the slit of the spectroscope, we may at any time see these prominences in all their fantastic and changing forms. The spectroscope in that case serves merely to diminish the light received into the instrument from our atmosphere by spreading it out over a long space. Professor Hale, Director of the Mount Wilson Solar Observatory, and Deslandres, of Paris, have each devised what is called the spectroheliograph, by means of which pictures of the chromosphere and the prominences may be taken by a single exposure around the entire disk of the sun. Some of these flames

reach a height exceeding the distance from here to the moon. Some of them remain practically unchanged for several days together, while others change very rapidly and assume most fantastic shapes. The chromosphere is seething with leaping flames. Sometimes there is a veritable explosion in the deeper parts of the sun and material is hurled to a height of three hundred thousand miles, with a velocity of three hundred miles per second, thus surpassing all our former conceptions of eruptive violence.

Now, matter is inert; hence all energy must emanate from the Creator. What evidences we have here of God's power! Think of the force necessary to throw matter three hundred thousand miles high, with the gravity of the sun pulling back upon it with twenty-seven and a half times the force of the gravity of the earth. Think of the force the sun is constantly exerting upon the planets, holding them under control as they wheel about him in their vast orbits. Think of the force necessary to give the earth its

orbital velocity of nineteen miles per second. We think that a terrific force which can throw a cannon ball with a swiftness which sends it crashing through the sides of an iron-clad. Then think of the force that can take a world and hurl it through space with a velocity eighty times as great. Remember that the heat of the sun is itself but another form of energy, and that for untold ages it has been pouring unceasingly into space. What a convincing demonstration of the existence of "a power to which no limits can be assigned, a power infinite and universal," leading us to exclaim in the language of inspiration, "The Lord God omnipotent reigneth. His greatness is unsearchable."

By comparing their positions at far-separated dates, most of the brighter stars are found to have motions of their own. It is very slight, the largest observed motion being only eight and one-half seconds of arc in a year. But even a slight lateral change at so great a distance implies very rapid motion. Of course, only that component of the star's

motion perpendicular to the line of sight can be measured with angular instruments. Two stars might have the same lateral motions while motions in the line of sight were in opposite directions.

There remains to be mentioned in this connection one of the most unexpected and marvelous achievements of modern science: nothing less than the discovery of a means of determining whether a source of light is approaching, receding, or at rest. The principle is easily understood. The different amounts by which different rays of light are bent in passing through a prism, giving the colored spectrum, depends upon the different velocities with which these rays pass through material media. In passing through a prism the short waves of violet light are more refracted than the long waves of red light. Now, if a source of light is approaching us, a greater number of light waves will reach us in a given time than from such a source at rest. This, in effect, is the same as shortening the waves, and all the lines of the

spectrum will be shifted toward the violet end. If the source of light is receding, a fewer number of waves will reach us in a given time, and the lines of the spectrum will be shifted toward the red end. In either case the velocity can be determined by the amount of displacement. As simple as this method seems, now that the discovery has been made, none but a genius of the rarest order would have caught the connection between cause and effect in a phenomenon where that relation is so subtile and apparently hopeless of detection. In this way it has been ascertained that some stars are approaching and some receding with velocities amounting, in some cases, to thirty or forty or even sixty miles per second. This method is so accurate that Mr. Keeler obtained, for the velocity of Arcturus, from observations taken at Lick Observatory on three different nights, results that differed from one another by only six-tenths of a mile, and the mean of all the observations differed by only one-tenth of a mile from the

mean of five determinations at the Potsdam Observatory. This is a marvelous achievement, especially when we consider that this star is so distant that the light with which we see it has been nearly two hundred years on its way. More than this: there are whole clusters of stars, like the Pleiades, moving in the same direction with a common velocity, constituting what is called star-drift. Many of these drifting systems are found in different parts of the heavens, revealing to us stellar relations unsuspected before and motions that are bewildering in their maze and rapidity.

By its power to show whether a star is approaching or receding, the spectroscope has brought to us another remarkable and wholly unexpected revelation. There are certain stars which give out very different amounts of light at different times. These are called variable stars. While in some of these the changes are quite irregular, in as many as twenty-five the changes are very regular and have definite periods. The most

striking of these is Algol, in the constellation Perseus. Most of the time it shines steadily as a star of the second magnitude; but suddenly it begins to wane and, in the short period of four hours, it diminishes to one-sixth of its former brilliancy. Remaining thus for about twenty minutes, it begins to grow in brightness and, after four hours more, shines with its original brightness. After a little more than two and a half days the same changes are repeated, its entire period being two days, twenty hours, forty-eight minutes, and fifty-five seconds. To account for the very regular changes of light in Algol, it had been suggested that a great dark body may be revolving about it, and that by passing periodically nearly between us and the star it obscures a part of the light. This would account for the changes observed; but it was a mere speculation, and nobody supposed that we should ever have any proof, one way or the other. Yet, strangely enough, the spectroscope has recently brought positive information regarding that theory.

It was in this way: We say in a general way that the moon revolves around the earth. What we really mean is that the two are revolving around their common center of gravity, which lies between them, only about three thousand miles from the earth's center. So if there is a body thus linked with Algol, the two are revolving around their common center of gravity between them. If our line of sight lies nearly in the plane of revolution, it is clear that when one is approaching, the other is receding. But, as just explained, the spectroscope reveals motions of approach and recession. When the dark body is approaching, preparatory to eclipsing the star by passing between us and it, Algol must be receding, and all the lines of the spectrum should be displaced toward the red end. After the eclipse has taken place and the dark body is receding, Algol must be approaching, and all the lines of the spectrum should be displaced toward the violet end. Spectroscopes of high power have been applied to this star, and those

very changes are observed, and in just that order, showing beyond question that the periodic diminution of light in this star is due to its being partially eclipsed by a dark body, or less bright body, that is in revolution about it. Moreover, since the distance of Algol and the time of revolution are known, we have the means of computing all the elements of the system, the distance apart of the two bodies, their relative size, and the mass of the two. While Algol blazes with eighty times the light of our sun, the mass of the two is only two-thirds that of our sun. This revelation strengthens our belief that other suns are accompanied by planets and that there are many systems like our solar system.

Closely allied to this revelation is another. Mr. Pickering, of the Harvard College Observatory, finds that when the spectroscope is applied to the middle star in the handle of the Big Dipper, the star Mizar, or Zeta, in the Great Bear, the calcium line K is seen to separate into two parts, coming

together again after an interval of fifty-two days, then separating on the other side and closing again after another interval of fifty-two days. What is the interpretation? What could cause displacement of the spectral lines other than motion in the line of sight? It means that this star, which appears single even in the most powerful telescope, is really double, that both components contain calcium, and that the two are in revolution about the center of gravity between them, the period being one hundred and four days. When they are moving at right angles to the line of sight the spectral lines are in their normal position and appear single, but in all other positions one is approaching and the other receding, causing the calcium line to double. This star is so far away that the light which brings this revelation started seventy-six years ago.

A still closer pair is that found in Beta Aurigae, the period of separation of the lines being only four days, and consequently the period of revolution being only eight days.

Indeed, these two components are so near together, less than three times the distance of the moon from the earth, that to see them separated with a telescope would require an object-glass eighty feet in diameter. As the largest object-glass now in use is only forty inches in diameter, the optical separation of these stars is quite beyond the range of possibilities. Yet we are just as sure of their separate existence as we could be if they were seen as two. They are so far away that the light with which we see them has been sixty-three years on the way, so that the latest news from them started sixty-three years ago. Two hundred such binaries are now known.

Geology shows that the earth was not created in the state in which we find it, but that it reached this state by an evolution extending through many ages. The question naturally arises, Were the sun, the solar system, the stars created in the states in which they now exist, or did they reach these states by evolutions extending through un-

told ages? If the latter, then the evolution is still in progress and we ought to find suns and systems in the various stages of development. Far off there in the depths of space may be seen a little haze of light, covering an insignificant space upon the sky. Apply the telescope and hundreds, sometimes thousands, of brilliant stars burst upon the sight. This is a so-called resolvable nebula. The mingled rays of its many stars give the hazy appearance when viewed with the unaided eye. Thousands and thousands of nebulæ of various kinds are known in different parts of the heavens; and while the early telescopes did not resolve them all into separate stars, more and more of them were so resolved as more and more powerful telescopes were constructed. Many astronomers believed that all of the nebulæ were composed of separate stars, and that sufficiently powerful telescopes would reveal them. Many nebulæ, however, gave no more evidence of resolvability under a high-power telescope than under a low-power one; and some

astronomers, Sir Wm. Herschel among them, believed that many nebulæ were irresolvable, that they were composed, not of separate stars, but of great masses of gaseous material. The telescope could prove only its inability to resolve them, but could not prove them irresolvable. The spectroscope, however, brings us absolute knowledge of their condition. When the spectroscope was for the first time, in 1864, directed to such a nebula, the planetary nebula in Draco, Sir William Huggins, on putting his eye to the tube, saw, not dark lines such as the stars give, but three bright lines. In writing of it he says: "The riddle of the nebula was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas." Here we have, then, primordial matter, by condensation of which suns and worlds are made.

There are many such gaseous nebulæ, all of them having a slightly greenish tinge; but by far the greatest number of nebulæ, hundreds of thousands of them, including the

spiral nebulæ, give a continuous spectrum, indicating, in connection with their extreme tenuity, that they are composed of countless millions of incandescent solid or liquid particles or small bodies. Here, too, we have primordial matter, but in a different state. Between these states of elemental matter and completed suns, or stars, we find many intermediate states of development. In some the nucleus has just begun to form, while in others it is well advanced, but with nebulous matter still surrounding it. In some the nebulous matter has all been collected into the central sun, doubtless with a retinue of planets, but giving evidence of being a new sun; while in others the light has begun to fade and the heat to decline. Through the motions they produce on the luminous suns with which they are connected, hundreds of others are known and thousands presumed that have lost all their light and swing as cold, dark masses in space.

"In the beginning," which means the beginning for our part of the universe, "God

created the heaven and the earth," which means our heaven, or firmament, and our earth. "And the earth was without form, and void; and darkness was upon the face of the deep." Out of this formless mass was developed, after how many ages we do not know, the earth as we know it. Astronomy, with the telescope, the camera, and higher mathematics, has magnified many million-fold the created universe. Not only this, but the spectroscope, that marvelous instrument, that wireless telegraph which receives and interprets messages from the remotest confines of the universe, shows us in its new revelation suns and systems in all the different stages of creation. "Lo, these are parts of His ways; but how little a portion is heard of Him! but the thunder of His power who can understand?"

On some matters our conceptions can easily go beyond all possible realization. We can easily conceive larger mansions, longer bridges, taller steeples, greater ships, more beautiful cities than any that have ever been

built. We can readily imagine swifter travel, more powerful engines, more perfect machinery than any that have ever been realized. We can easily conceive juster governments, purer municipalities, better people than any we have ever known. In some other matters, however, our conceptions can be formed only as we realize the subject of them. For example, one whose surroundings had been such as to prevent his hearing any music except that of a very primitive sort would readily admit, on hearing for the first time a fine orchestra, that the music was far beyond any conception he had ever formed. There are perfumes and flavors more exquisite and pains more excruciating than any we could conceive without the realization.

So the spectroscope reveals to us in God not only a power, a wisdom, a majesty, but also a conformity to plan, a uniformity of method, systematic and intelligent adaptation of means to ends which we would not otherwise conceive.

And what are the ends to which these

numberless suns and controlled systems are means? The spectroscope shows that nearly a fourth of all the stars examined are like our sun, while the others are either approaching this state or have already passed it. As Professor Comstock says, "The change from one type to another is by insensible gradations, like the transition from youth to manhood and from manhood to old age." We are intimately acquainted with one of these suns, and we know that its use is to light and warm a system of revolving planets. We infer from analogy that the other suns are for the same purpose. We are intimately acquainted with one of these planets, the earth on which we live, and we know that it is lighted and warmed for supporting life. We infer from analogy that at least some of the other planets of our system and countless numbers of planets of other systems are lighted and warmed for the same purpose, and are the abode of life, possibly of intelligent, moral beings. This speculation will be pursued farther at the close.

II

REVELATION THROUGH THE TELESCOPE

ASTRONOMY can not, like most sciences, be traced to its source, unless we choose to regard that source as contemporaneous with the origin of the race itself. As far back as history and even tradition can trace we find men profoundly interested in the study of the heavens.

The writings of the poet, the philosopher, the divine, in all ages, show how their souls have been moved by the contemplation of the heavens. The great ones of earth have rendered homage to the science of the stars, and the humble, as well, in all ages and lands have stood at times and beheld in solemn awe "the shining hosts of heaven moving onward in silent grandeur."

Leaving profane history and consulting

the Sacred Record, we find that earth's earliest inhabitants had looked upon the sublime spectacle of the evening sky with delighted eyes. Moved by the majesty of the heavens, the sacred writer magnifies the Creator through them, exclaiming, "Lift up thine eyes on high, and behold who hath created these things, that bringeth out their host by number?" Job says: "He stretcheth out the north over the empty space, and hangeth the earth upon nothing. By His Spirit He hath garnished the heavens; His hand hath formed the crooked serpent." Israel's poet king, whose eyes were often turned devoutly toward the stars, says: "The heavens declare the glory of God; and the firmament showeth His handiwork. Day unto day uttereth speech, and night unto night showeth knowledge."

If, then, to the ancients, to whom the stars were but studs fixed to the rigid vault of the sky and the planets were bodies of inconsiderable size at insignificant distances from the earth, the heavens presented a

sublime spectacle, what limitless scenes of grandeur open to us, to whom the stars are magnificent blazing suns, the planets vast globes, most of them far surpassing the earth in size; to us whose vision, with telescopic aid, can pierce ten thousand times farther into space and evoke from those profound depths millions more of blazing suns! And if they, though ignorant of the true system of the universe, recognized it as the work of intelligent design and were able to find a Sovereign worthy to be worshiped and adored, what exalted conceptions ought we to obtain of the great Architect of the universe!

To pursue astronomy merely as a part of a liberal education, or for use in navigation, surveying, and the time service, or for affording "scope to the mathematician's skill," would be to overlook its noblest province, which should be to trace the Divine perfections as manifested in every part of the heavens. Nowhere else are the attributes of the Divine so impressively displayed; no-

where else do we have such convincing evidence of the greatness of His power and wisdom. Milton has well said, "Heaven is as the Book of God before us set, wherein to read His wondrous works."

In the preceding pages we have dealt mainly with the revelations of the spectroscope. For analyzing terrestrial substances the instrument is complete in itself, but for application to celestial bodies it is combined with the equatorial telescope. This is for the double purpose of gathering more light and of taking advantage of the clock-work of the equatorial to counteract the apparent westward motion of the stars, due to the eastward rotation of the earth on its axis. But long before the spectroscope made its appearance in the astronomical field, which was in 1859, the telescope had been making wonderful revelations regarding the heavens. The telescope has its applications not only in the great equatorial, but also in the meridian circle, for determining, just as they are crossing the meridian, the positions of bodies;

the heliometer, for the measurement of small angles; and the astronomical camera, for photographing celestial objects. The little telescope of Galileo, constructed by himself in 1610, made revelations so astonishing that men could scarcely believe them. Among them were the mountains and valleys on the moon, spots on the sun, the satellites and belts of Jupiter, the phases of Venus like those of our moon, and the rings of Saturn. As the size of telescopes has gone on increasing from this little instrument to the great Lick telescope, with an object glass thirty-six inches in diameter and focal length of fifty-six feet, and to the still greater Yerkes telescope, with object glass forty inches in diameter and focal length of sixty-five feet, and gathering thirty-five thousand times as much light as the unaided eye, the revelations have been more and more astonishing. Only those pertaining to the fixed stars will be considered in what follows.

Although the stars have always been objects of interest, have guided the mariner over

trackless seas, and have inspired many sublime and noble thoughts, yet, until a comparatively recent date, only three things were known about them, *viz.*, that they retain, approximately, their relative positions, that they are self-luminous, and that they are very far away.

The remotest planet of our own system is at no insignificant distance. It is difficult for us to comprehend it when expressed in terms of any unit used in terrestrial measurements. The distance from the sun, and consequently the mean distance from us, is 2,775,000,000 miles; but miles lose their meaning in such a number. An express train, running day and night at the rate of thirty miles an hour, would be over 10,500 years in making this journey. Had the ball of the first cannon fired in the Revolutionary War continued in a straight line with the velocity with which it left the muzzle, it would now be less than half of the way to the orbit of Neptune. So far as known, this is the limit of our system, with the exception of a

number of comets which, in their eccentric orbits, plunge far beyond. And what a distance it is! Merely to think of it almost makes us dizzy.

But astronomers were not satisfied when they had reached the limits of our own system, and obtained a knowledge of the motions of its bodies and the laws by which they are governed. Success stimulates the mind and urges it to new efforts and greater achievements. Knowing that our whole planetary system is but a small part of the universe, they were anxious to pass its boundaries and leap the mighty gulf that separates us from the fixed stars. Many attempts were made to sound the depths in which they are sunk, but all in vain; many promising methods were tried, but to no purpose, until Prussia gave to the world a Bessel; and Bessel it was who led the way across this bewildering distance.

The distance to the sun is measured by solving the triangle formed by conceiving a line drawn from the sun to the center of the

earth, another from the sun tangent to the earth, and the radius of the earth at the point of tangency. The angle at the sun is known as the horizontal parallax. As the triangle is right-angled at the point of tangency, the radius of the earth divided by the sine of the parallax will give the distance to the sun. You are familiar with the fact that one way of obtaining this angle is by means of the transit of Venus, and know that at times of its occurrence all civilized nations have sent out scientific expeditions to observe it, with the view of obtaining an accurate value of the parallax.

This method, however, is wholly inapplicable to the measurement of the distance to the fixed stars, for so great is their distance that the angle at a star subtended by the earth's radius is entirely inappreciable. It was necessary to look for a longer base line. Our annual journey around the sun furnishes one of great length. Now we are 93,000,000 miles on this side of the sun; in six months we shall be 93,000,000 miles on

the other side; that is, we shall be 186,000,000 miles from where we now are. Notwithstanding this mighty change, in six months we shall look in the same direction for the North Star. Aye, more: so slight is the displacement that it can not, by direct measurement, be determined with the most accurate instruments.

It was necessary to devise some other method of determining the parallax of the fixed stars. Sir Wm. Herschel was the first to attempt to apply one which had been suggested by Galileo. The telescope often reveals two stars where the unassisted eye detects but one. These two stars are not necessarily near each other, but may appear so only because situated nearly in the same straight line with the observer. When one of them is much smaller than the other, it is presumably much farther away. Now, if the farther one is a little east of the nearer one, a movement on our part toward the east would cause them to separate still farther, and a movement toward the west

would cause them to approach nearer to each other. With such a point of reference, a very slight change could be measured with delicate instruments, and by taking several such points of reference, still greater accuracy could be secured. Herschel began his observations upon such a pair of stars, measuring as frequently as possible and with great care the distance between the two, and noting the direction of the line joining them. Soon a change was observed; but, strange to say, it agreed neither in time nor direction with the motion which parallax would give. Judge of his astonishment when he discovered that the two stars were revolving around a common center between them. He examined several other pairs with the same result.

Thus was the effort to measure a star parallax again defeated; but rich discoveries were rewarding those who were seeking what began to seem as unattainable as the philosopher's stone or the mythical Eldorado. Munich now had her Fraunhofer, who had acquired wonderful skill in the construction

of refracting telescopes, and Koenigsberg had her Bessel, who was without a superior in the mathematical and astronomical field. The combined efforts of these two geniuses produced the celebrated Koenigsberg heliometer. Provided with this wonderfully delicate and ingenious instrument, Bessel undertook the accomplishment of what had baffled his predecessors. His method differed from Herschel's only in his choosing for points of reference two minute stars that were farther removed from the one whose parallax was sought. After most careful and oft-repeated measurements, Bessel detected a variation, agreeing exactly in time and direction with what parallax required; but it was so slight and gave such an astounding distance that he hesitated. He pursued the investigation through another year and obtained the same result. Still fearing that there might be some mistake, he repeated his observations through another year, and, as the values were the same, all doubts were dispelled, and Bessel announced to the world that he had

crossed the hitherto impassable abyss and measured the distance to one of the fixed stars, 61 Cygni. But how shall we obtain a conception of the amazing distance? Miles, velocities of express trains, and swiftly flying cannon balls fail to give us an adequate unit. Light, which flashes with a swiftness that will carry it eight times around the world while the clock ticks once, occupies nearly eight years in completing this mighty journey. The subsequent observations of Peters at Pulkova and Johnson at Oxford have confirmed Bessel's result.

There is at least one star, Alpha Centauri, nearer than 61 Cygni, whose light requires four and a half years in coming to us. From Sirius, the brightest star in the heavens, the light comes in eight and a half years; from Alpha Lyrae, in twenty-one and three-fourths years; from Aldebaran, in twenty-nine and a half years; from the North Star, in forty-four years; from Capella, in seventy years; from Sigma Draconis, in one hundred and twenty-nine years. If the star Alcyone

of the Pleiades should be blotted from existence to-night, it would continue to be seen here for more than five hundred years, for the light which starts from there to-night can not reach the earth before the expiration of that time. These distances should be taken with some latitude, as a slight error in so small a parallax makes a great difference in the distance.

Thus with instrumental aid and mathematical analysis does the universe expand before us; and thus expand our conceptions of the Great God of the universe, as we peer farther and farther through space and perceive the limitless extent of His domain.

After learning that the stars are separated from us by such incomprehensible distances, we are naturally desirous to know something of their size. In the telescope they present no appreciable disk; and hence their diameter can not be measured. Even in a telescope with a magnifying power of several thousand they appear as points; that is, their disk is so small that several

thousands of times that disk is still inappreciable. Then are astronomers baffled? Are they compelled to admit that their micrometers are powerless and say, The stars are so far away that their size can not be determined, even approximately? As has been stated, there are many Binary Stars, or pairs in which one is revolving around the other. It is easy to demonstrate that the masses of bodies are to each other directly as the cubes of the mean distances of any bodies which revolve around them, and inversely as the squares of the times of the revolution. Procyon is thus found to have half the mass of our sun; 70 Ophiuchi, one and eight-tenths times the mass of our sun; Alpha Centauri, two times the mass of our sun; Sirius, three and a half times the mass of our sun; and 85 Pegasi, eleven and one-third times the mass of our sun. We can determine the amount of light emitted by any star whose distance is known; then, allowing for the greater distance, we can compare the amount of light emitted by the star

with that emitted by the sun. It is thus found that 61 Cygni gives one-tenth as much light as our sun; Alpha Centauri, two times as much; Vega, forty-four times as much; the Pole Star, sixty-eight times as much; Betelguese, five hundred times as much; Arcturus and Regulus, each one thousand times as much; while Canopus, next to the brightest star in the heavens, blazes with the light of at least ten thousand of our suns. This last star is so remote that Doctor David Gill, astronomer at the Cape of Good Hope, was not able to detect the slightest parallax, although his long-continued series of measurements would have revealed as slight a parallax as one-hundredth of a second. We can say, therefore, that Canopus is not nearer than a parallax of one-hundredth of a second would give, and consequently that its light can not be less than ten thousand times that of our sun. Rigel and Alpha Cygni blaze quite as gloriously. We remember that the sun is more than a million and a quarter times larger than the whole earth; and yet

there are Canopus and Rigel and Alpha Cygni each constantly flinging off into space ten thousand times as much light. Well might the sacred writer exclaim: "O Lord, my God, Thou art very great; Thou art clothed with honor and majesty; who coverest Thyself with light as with a garment: who stretchest out the heavens like a curtain. Lo, these are parts of His ways; but how little a portion is heard of Him! but the thunder of His power who can understand?"

In the presence of magnitudes so overpowering to the mind and distances that fairly stagger the intellect, what significance attaches to these words of the psalmist: "When I consider Thy heavens, the work of Thy fingers, the moon and the stars which Thou hast ordained, what is man that Thou art mindful of him? and the son of man that Thou visitest Him?" Ah! in that moment of abasement, when he felt himself so insignificant a part of the vast universe, there came another thought, and in the very next breath he exclaimed, "Thou hast made him

a little lower than the angels and hast crowned him with glory and honor." What is man that Thou art mindful of him? Thou hast given him a mind, capable, to some extent, of appreciating Thy wondrous works and Thy wondrous self. What is man that Thou art mindful of him? Thou hast given him an immortal soul, and when these vast suns that now blaze with so much splendor shall swing in space as cold and blackened masses, man shall live onward through the endless ages of eternity.

Many peculiarities, not seen with the unassisted eye, appear when the stars are viewed through a telescope. One of these, the duplex character of many stars, has already been mentioned. When Sir Wm. Herschel began his observations upon these stars, in 1780, he knew of only four; but he extended the list to five hundred, and the number is now known to exceed twelve thousand. Some of these appear double simply because one star, though an immense distance from the other, is situated nearly behind it. Many

of them, however, are physically connected and constitute magnificent systems of revolving suns. These are called Binary Stars. Alpha Centauri is one of them, and Sirius is another. In all, about five hundred are known. Of these there are fifteen whose periods are less than a century, and more than a hundred whose periods are less than a thousand years. There are instances of triple and quadruple stars that are in revolution about a common center. More than this: there are whole clusters, like those in Hercules and Centaurus, which undoubtedly form a system and revolve, age after age, in obedience to the same great law of gravitation which holds the planets in their orbits about the sun.

Newton first proved that gravitation, which causes bodies at the surface of the earth to fall, extends also to the moon. He next demonstrated that it extends to all the bodies in the solar system; and then, by a generalization as sublime as it was broad, rose to the great law that every body attracts

every other body by a force that varies directly as the mass and inversely as the square of the distance. It was not established beyond our system, however, until it was found that binary stars, in the remote depths of space, revolve in exact obedience to this law. And thus we have proved to us the unity of design and the unity of law throughout the boundless universe. The farther we penetrate into the profounds of space, the more august and astonishing the scenes we behold and the more are we impressed with God's inscrutable wisdom and marvelous perfections.

Nothing speaks so forcibly of the existence of an Intelligent Creator and Ruler as the operation of general laws. A law implies a law-giver. When we discover a new law, we have simply discovered another of the ways in which the Ruler of the universe works His sovereign will. How many of these general laws are found in the system controlled by the sun, laws in whose unvarying operation and continuance we have the

utmost confidence. For example: The planets all move in ellipses around the sun; the radius vector in each case describes areas that are proportional to the times; the squares of the times of revolution are to each other as the cubes of the mean distances from the sun; the times of axial rotation and of revolution around the sun are essentially constant for each planet; attraction varies directly as the mass and inversely as the square of the distance. These are a few of the laws regulating our system. It was after the discovery of one of them, at the end of seventeen years of search, that Kepler, in his devout enthusiasm, exclaimed, "O God, I think Thy thoughts after Thee!" Yes, when we have found a law, we have caught the very thought that was in the mind of God at the creation. Let us not place the law for the law-giver. What, for example, is that force we call gravitation? In what does the power of attracting consist? Let us not be deceived; gravitation is but a name. We can not conceive the nature

of the force. All we can say is, that the great First Cause is pleased to guide the orbs of heaven by an unvarying law, that man has attained to a knowledge of that law, and has named it gravitation. This power was not only impressed by the Creator, but its continuance is every moment dependent on His sovereign will. Let but His will cease acting and the planets would shoot madly from their orbits and there would be "wreck of matter and crush of worlds."

And what a lesson we have here of God's stability. He knew from the beginning what laws would secure the perfection of harmony. Astronomers know that for three thousand years these laws have not changed one iota, and there is no evidence that they have ever changed. Surely, with God there is "no variableness, neither shadow of turning." "From everlasting to everlasting Thou art God; . . . the same yesterday, to-day, and forever."

As indicated in another connection, if the

telescope be directed toward Algol, the observer will witness a strange phenomenon. The star, which has been shining steadily as one of the second magnitude, begins to wane, and, under the eye of the observer, in four hours sinks to a star of the fourth magnitude. After twenty minutes it begins to increase, and in four hours more shines again as a second magnitude star, remaining thus a little more than two and a half days, when the same changes are repeated. Mira, or the Wonderful, a star in the Whale, varies between still greater extremes, sinking from the second to the ninth magnitude, thus diminishing from a bright star to entire invisibility, passing through all its changes in less than a year. In fact, so great is the change in these two stars that it may be observed by the unaided eye. Beta Lyrae varies from the third to the fifth magnitude, and back to the third in less than thirteen days. Xi Cygni dwindles from the fourth magnitude to the thirteenth, far below the range of visibility, and then returns to its

former brightness in four hundred and six days. More than three hundred of these periodic stars are known. Many others are irregularly variable.

A still more strange, even startling, phenomenon is the sudden blazing forth of a star in a part of the heavens where none had been observed before. The first occurrence of this kind on record is that observed by Hipparchus more than two thousand years ago. Biot finds in Chinese chronicles an account of the same new star. This star was so brilliant that it was visible in the full light of day. Tycho Brahe says that one evening in 1572 he "found a group of country people gazing at a star [in Cassiopeia] which he was sure did not exist an hour before." For three weeks it shone with a splendor surpassing that of Sirius, the brightest star in the heavens. It then began to diminish, and in sixteen months entirely disappeared from view. Kepler describes a new star which in 1604 made its appearance in Ophiuchus. It resembled Tycho's star in brightness and

duration. Many other instances of the sudden appearance of stars are on record. A new interest was awakened in these anomalous bodies by the appearance of one in 1866 in the Northern Crown, one in 1876 in the Swan, one in 1901 in Perseus, and others. The science of spectrum analysis had been developed, and astronomers were anxiously waiting with their spectroscopes to learn what these strange bodies had to say concerning their brilliant but brief career. A marvelous science is that which enables us to determine not only the materials of a body situated millions of billions of miles from us, but, in many cases, the conditions in which those materials exist, and even the velocity with which the body, in its great orbit, is approaching or receding. The gem in the Northern Crown shone on the night of its first appearance as a star of the second magnitude; the next night, of the third magnitude; the fourth night, of the fourth magnitude; the fifth night, of the fifth magnitude; the seventh night, of the seventh magnitude;

and in two weeks, of the ninth magnitude. The new star in the Swan, when first seen, in November, 1876, was of the third magnitude. In three and a half months it had sunk to the eighth magnitude, which it still retains. The new star in Perseus, when it was first seen in February, 1901, had the brightness of the Pole Star, and two days later was next to the brightest star in the heavens. So rapid was its growth that in three days its light was multiplied at least twenty-five thousand times. In a month it dwindled to bare visibility to the unaided eye.

We are not for a moment to suppose that these new stars, as they are called, are new in the sense that stars have suddenly begun to exist where none existed before. They were there all the same, but invisible. After the cause which renders them visible ceases to act, they again become invisible, but do not cease to exist, nor even change their position in the heavens. The variable stars have definite and, in many cases, well known periods. It is more than probable

that some of the so-called new stars do not differ from these except in the length of their periods and, in some cases, in becoming so indistinct that they can not be seen even with the telescope. In fact, the new star described by Tycho seems to be the same that blazed out on two preceding occasions at intervals of about three hundred and twelve years. The new star in the Northern Crown occupies the place of a ninth magnitude star recorded in Argelander's charts and catalogue.

The spectroscope revealed, in the last three new stars named above, the presence of large quantities of glowing hydrogen and other gases; that is, showed that they were intensely hot. And what a stupendous conflagration it must have been to render an invisible star so brilliant that it could be seen in the full light of day. The great Chicago fire would have been barely visible at the distance of the moon, our nearest neighbor, as a bright speck on the earth's surface. Think, then, of the conflagration that could

be seen billions of miles, with the sun shining in full splendor. Perhaps for the planets encircling those stars the time had come when "The heavens should pass away with a great noise, and the elements melt with fervent heat." Verily, "The pillars of heaven tremble and are astonished at His reproof."

As stated before, by comparing their positions at different dates, most of the brighter stars are found to have changed their positions slightly with reference to the stars in the same locality. In one star this motion amounts to seven seconds annually, and in another to eight and seven-tenths seconds annually. Arcturus has changed more than a degree since catalogued. The term "fixed stars," then, is a misnomer. A few years ago Mr. Proctor, after having pictured the proper motions of about twelve hundred stars, expressed his belief that groups of stars are traveling in a common direction with a common velocity, and denominated these groups "star-drift." Among others, he called attention to such a group in Ursa Major. Of

course, only that portion of the star's motion perpendicular to the line of sight could be thus pictured. Two stars might have the same side-wise motions, while their actual motions were very different. Nevertheless Mr. Proctor was convinced that Beta, Gamma, Delta, Epsilon, and Zeta, in Ursa Major, are moving in the same direction with the same velocity, and that Alpha and Eta, of the same constellation, do not belong to this drifting system.

As explained before, one of the marvelous powers of the spectroscope is that of revealing whether a star is approaching, receding, or at rest. If the star is approaching, the lines of the spectrum are shifted toward the violet end; and if receding, the lines are shifted toward the red end. To ascertain the velocity due to a given displacement, the astronomer uses a mathematical formula. We have one very striking instance of a known velocity and the resulting displacement. As the sun, like the earth, rotates on its axis from west to east, the eastern margin

at any time is approaching us and the western margin is receding from us. As the time of rotation and the diameter of the sun are known, the velocity of approach and recession at points on the equator is readily computed. Now, if the spectroscope be directed toward the eastern margin of the sun, where the matter is approaching us, the spectral lines will be shifted toward the violet end; and if it be directed toward the western margin, the spectral lines will be shifted toward the red end. Evidently half of this total displacement will be the amount of displacement due to the known velocity at the sun's equator. This furnishes a standard by which we may determine unknown velocities.

The displacement of the spectral lines of an approaching or receding star may be readily detected by throwing beside or upon its spectrum, by means of a comparison prism, the spectrum of some terrestrial substance, as hydrogen, sodium, iron, or titanium. The spectral lines of the terrestrial substance will be in their normal position,

while those of the star will be shifted toward the violet or the red end, according as it is approaching or receding. For accuracy of measurement these spectra are photographed, the rather indistinct lines of the star's spectrum becoming sharp by long exposure, and then the displacement is measured on the plate under a microscope. We are assured by a specialist in this work that the best observers with the best instruments can determine within a quarter of a mile the velocity per second of an approaching or receding star. In velocities of thirty, forty, or fifty miles per second this is slight error. Of course, the known orbital velocity of the earth must be eliminated from the results. By this method Doctor Huggins learned that Sirius is rapidly receding from us—so rapidly, in fact, that some time in the distant future it will be robbed of the distinction of being the most brilliant star in the heavens. His instrument being of insufficient power to enable him to deal with the less brilliant and less rapidly moving stars, the Royal As-

tronomical Society appropriated sufficient money for the construction of a superior instrument for his use. He with this instrument and later observers with better instruments ascertained that some stars are approaching us and some receding from us with velocities amounting, in some cases, to thirty or forty or even sixty miles per second. Mr. Proctor was naturally anxious that his "star-drift" should be subjected to this test, and must have been much gratified when he received from Doctor Huggins a letter stating that the stars in Ursa Major had been examined with the Royal Society's new instrument, and that Beta, Gamma, Delta, Epsilon, and Zeta were all found to be approaching the earth with a velocity of about seventeen miles per second, thus constituting, according to Mr. Proctor's prediction, a true drifting system. The same test showed that Alpha and Eta, of the same constellation, are also approaching, but with a different velocity, thus confirming in every particular Mr. Proctor's sagacious inference. Another

such drifting system is the beautiful cluster known since the time of Job as the Pleiades. Not only the seven stars visible to most eyes, but also as many as forty-five of the telescopic stars and the great nebulous masses which photography reveals in the same cluster, are sailing together majestically onward with a common velocity. Many of these drifting systems are found in different parts of the heavens.

After learning that other suns are in motion, we are naturally led to inquire whether our own sun, with all its attendant worlds, is not revolving around some far-off center. Let us examine the evidences and judge for ourselves. We have seen, from observations upon the Binary Stars, that the law of gravitation extends throughout space. This fact alone affords a proof that suns everywhere are in motion, for, if they attract one another, there must be revolution to give an equal force in the opposite direction to prevent their rushing together. If the orbital motions of the planets in our system

should cease, the planets would be dashed into the sun. Let us see what the following phenomena indicate: In the region occupied by Orion, the River Po, and the Dove, in the southern heavens, the stars are drawing nearer to one another; while the stars in Hercules, the opposite space in the heavens, are gradually separating. There is but one conclusion to be derived from this, *viz.*, that the sun, with all its planets and comets, is moving onward through space toward the constellation Hercules. The results of Maedler, Argelander, the Struves, Airy, Dunkin, Galloway, Boss, Stumpe, Porter, and Newcomb, who have examined the evidences with the view of ascertaining the point toward which the sun is now moving, differ by only a small amount. Spectroscopic examination of a large number of stars in this locality and the opposite one shows, by the average displacement of the lines, a velocity of about eleven miles per second. Even with this velocity it requires more than eighty thousand years to sweep over a

distance equal to that from here to the nearest star.

All are familiar with the appearance of the Galaxy, or Milky Way. It looks like a misty, hazy belt spanning the sky; but the telescope, as is well known, shows it to be composed of countless numbers of stars. They are probably not much nearer to one another than the nearest stars are to us, but there are so many of them scattered through deeper and deeper space that their mingled rays give us this cloudy appearance. It has been estimated that from the remotest Milky Way stars visible through our telescopes the light requires at least five thousand years in coming to us. Nor is that all. When we have reached the limit of the space-penetrating power of the largest telescopes, a power that reveals in the entire heavens more than a hundred million stars, we may attach the photographic camera, give long exposure, and obtain the images of millions more. The effect of the light is cumulative, and by acting continuously through several hours upon

the same part of the sensitive plate, it renders visible, in a sense, the invisible. Eighteen observatories in different parts of the world have been co-operating in photographing the entire heavens. While the main object is to ascertain, by comparison with similar photographs some years hence, what changes will have taken place, incidentally these plates reveal to us the existence of countless multitudes of stars that are beyond the ken of even our greatest telescopes. Nor is that all. As stated previously, if the telescope be applied to one of those little patches of haze, for example like that in Hercules, which has an angular diameter only one-fourth of that of the moon, it is found to be composed of thousands of brilliant stars. The great cluster Omega Centauri contains more than five thousand stars. It is thought that light occupies not less than four hundred years in coming to us from this cluster. If so, then the cluster is so vast that for light to flash across its diameter requires more than four years. More than

two hundred such clusters are known. Nor is that all. Yonder are other patches of haze which are not resolved into multitudes of stars, even with the most powerful telescope. These are the nebulæ proper. As stated before, the spectroscope shows that these nebulæ are composed, in some cases, of luminous gas and, in other cases, of luminous solid particles. Some of them are of enormous size. That in the sword handle of Orion, for example, covers several square degrees. While its distance is unknown, it is certainly greater than that to the nearest star; hence it would far more than fill the space enclosed by the orbit of the remotest planet of our system. The great nebula in Andromeda is nearly as large. These are probably suns in the making, the nebulous matter gradually condensing around the nucleus. More than a hundred and twenty thousand of such nebulæ are known. Nor is that all. The wonderfully sensitive plates of the photographic camera are, by long exposure, continually revealing more and more

of these nebulæ, "far-sunk in the depths of space."

This investigation is not without its lessons. Go out beneath the starry sky at night and see scattered upon heaven's high vault, in such wonderful profusion, those bright orbs; apply the telescope to yon space that seems utterly void and see there hundreds more of those glittering stars; know that for every star visible to the unaided eye the telescope reveals a million; know that for every star visible by the largest telescope the photographic plate, with long exposure, reveals multitudes more; then remember that each particular star is a sun, on the average as large, as magnificent as our own, and deny, if you can, the glory of the Creator.

Look at this massive earth supported in space; from that rise to Jupiter, fourteen hundred times as large; from that rise to the sun, more than a million and a quarter times as large; see our whole mighty system, as Doctor Burr says, "Sailing down the abyss as if driven by ten thousand hurri-

canes," and deny, if you can, the almightiness of the Creator!

See the moon floating so majestically around the earth; see the earth and the other planets revolving with such sublime precision around the sun; remember that the sun with all its retinue of worlds is, with dizzying swiftness, flying through space; see those nebulæ, so far, far away in the infinite depths, doubtless revolving around their respective centers; know that all of these stars and star systems and nebulæ are rushing through the infinite universe of space in wonderful curves that are the resultants of their initial velocities and mutual attractions—motion everywhere—with no jarring, no interference, no commotion, and deny, if you can, the infinite wisdom of the Creator and Controller of all this complexity. Well might the sacred writer exclaim, "The heavens declare the glory of God, and the firmament showeth His handiwork; day unto day uttereth speech, and night unto night showeth knowledge."

This leads us to inquire, For what purpose were the stars created? Was it simply for the benefit of the earth? They certainly diminish the darkness of night a little, give us a beautiful nocturnal sky, and the astronomer and the navigator use a few of them to determine longitude, latitude, and time. But if this is the only use, why were they, in countless millions, created in those depths so remote that our eyes never see them? If the stars serve no purpose other than the benefit they confer upon the earth, then is nearly the entire universe of no use, for the part visible to the eyes of man is the merest fraction of the whole. Or are they, perhaps, to diffuse light through the depths of space? What would we think of the policy of the Government should it cause lamps to be set up all through the Dismal Swamp to dispel the gloom? What is the use of dispelling the gloom when none are there to be affected by it? What is the use of lighting this dismal place if no eyes are there to receive the light? Could we take a journey

through the universe, what would we think of the Creator should we find that these unnumbered millions of vast suns serve no other end than to diffuse a useless splendor through the emptiness and solitudes of space? Let us not thus impeach the wisdom of the Most High. If in His works which we can examine we find wisdom displayed in all the appointments, we must assume that the same wisdom characterizes all His works. From what we know of His adapting means to ends, we can affirm positively that the stars must have a use commensurate with their magnitude and splendor. What, then, is that use? What could it be but to give light and heat to other worlds? And what could be the object of giving light and heat to other worlds but to support life upon them? On account of their being non-luminous and much smaller than the suns to which they belong, we could not expect to see these worlds at distances so vast.

For the following reasons I believe that the other suns control systems of planets and

that these and some of the other planets of our own system are not only the abode of life, but that they are inhabited by intelligent beings:

First. So far as at least some of the planets of our own system are concerned, it is fairly inferred from the condition of the bodies themselves. Like the earth, they have changes of seasons, alternation of day and night, are diversified with mountains and valleys, and are provided with water or similar liquid, and atmosphere. They therefore seem to possess the conditions necessary to support life. Some seem not yet to have reached this stage, and others may have passed it.

Second. I believe it because of the economy seen everywhere in nature. The whole surface of the earth is covered with vegetable growth, and earth, air, and water are teeming with animate existence. Where higher orders can not exist, lower orders are found. Indeed, so economical is Nature that she utilizes for the support of life situa-

tions where we would never expect to find it—the burning tropics, the frigid north, stagnant pools, decaying matter, and even the tissues of other living animals. So prolific is life that in a single drop of stagnant water the microscope reveals myriads of living creatures. Look where we will, we see that matter is subservient to life, and that Nature regards it as valuable only so far as it can contribute to the support and happiness of living beings. Just as the mind or soul is far superior to the body in which it dwells, animated existences are far superior to the dead earth which they inhabit. Then, since God has filled the earth with every conceivable form and variety of living things, and has made it so evident that the earth was created for these, is it reasonable to suppose that those great planets of our system, one of which is fourteen hundred times larger than the earth, always have been and always will be devoid of life, and that they swing, age after age, through their vast orbits for no purpose but to be looked at by

us? This would prove God far more devoid of wisdom and true economy than the farmer who should cultivate to the highest perfection the ground in a single fence-corner and leave his other thousand acres untilled. If to leave the planets of our own system uninhabited would be an extravagant waste of material, incomparably greater would be the waste if those millions of suns, many of which are known to be vastly larger than our own, illuminate no inhabited worlds, but lose their useless rays in the "silent solitudes of immensity."

Third. I believe it as a consequence of God's eternity. Eternity is a necessary attribute of the Creator. Now, to say nothing of the statement of revelation, which is explicit, geology proves that the earth has been occupied with animal and vegetable life for a comparatively short period; and geology and astronomy together prove, and revelation asserts, that in a comparatively short period it will be unfitted for the support of life. Then, if the earth is the only world in

the universe that is inhabited, what has God been doing through all the eternity of the past, and what is He going to busy Himself with through the eternity of the future? Is it compatible with our ideas of Divine power and wisdom and beneficence that He should spend the eternity of the past in preparing one small place of habitation, cause it to be occupied by intelligent beings for a few thousand years, and then spend all the eternity of the future in making happy the few that have proved themselves worthy to come up higher? Surely God, who is from "everlasting to everlasting," Infinite God, "who inhabiteth eternity," would not confine what He evidently regards the crowning work of His creation to so short a period.

Fourth. I believe it because of God's beneficence. We see on every hand evidences of His goodness. Indeed, His desire to communicate happiness constitutes His chief attribute and His whole moral character. In the Scriptures this is very positively declared. It is stated not simply that God is

loving in His nature, but that "God is love." He is the very essence of love. Indeed, "God so loved the world that He gave His only begotten Son, that whosoever believeth in Him should not perish, but have everlasting life." Now, benevolence and love can not be exercised toward rocks and wastes, nor towards planets and suns, but toward sentient beings alone; and if only this little speck of the universe is inhabited, the exercise of this attribute is not commensurate with His power and wisdom. It would be confined to this earth, and only His power and wisdom would extend to the other planets and those millions of vast suns. We must believe that His beneficence, like all His attributes, is infinite and, hence, that other worlds are recipients of His love. Isaiah characterizes as folly the creation of a world without inhabitants. He says (45: 18): "God Himself formed the earth and made it; He hath established it, He created it not in vain, He formed it to be inhabited." This plainly implies that he would have regarded

it as having been created in vain had it not been inhabited. Infinitely more vain, then, would it be to create a vast universe which, with the exception of one small world, a very mote in comparison with the whole, should be devoid of inhabitants.

We must, then, look upon the myriads of suns as centers of revolving worlds, some of which are doubtless inhabited not only by sentient beings, but by intelligent, moral beings. What a noble conception does this give us of the great God of the universe! Instead of having only one small world under His sway, we contemplate Him as Ruler of thousands of millions of worlds as they incessantly revolve through their appointed courses.

One hundred million suns are visible through the largest telescopes, and countless millions more are revealed by the cumulative effect of light by long exposure upon the sensitive photographic plate. How boundless, then, is the empire over which not only the creative power, but the moral govern-

ment of the Most High prevails! Well might the psalmist ask: "Whither shall I go from Thy Spirit or whither shall I flee from Thy presence? If I ascend up into heaven, Thou art there: if I make my bed in hell, Thou art there." And since through all this boundless domain, among His infinite host, He displays the majesty of His power, the depth of His wisdom, the riches of His beneficence, the glory of all His perfections, how consistent is the appeal from the full heart of the inspired writer: "Praise ye Him, all His hosts. Praise ye Him, sun and moon; praise Him, all ye stars of light. Praise Him, ye heavens of heavens; . . . for His glory is above the earth and heaven."